

Soil Survey Technical Note No. 8

Use of Reaction (pH) in Soil Taxonomy

Purpose

This technical note, slightly revised, was originally distributed in 1993 under the Soil Survey Technical Note series of the National Soil Survey Center. It became obsolete in 2001 with the advent of the new NRCS directives system for posting Soil Survey Technology Notes at <http://policy.nrcs.usda.gov/scripts/lpsiis.dll/TN/TN.htm>. This re-issue contains information that is still valid and pertinent to the taxonomic classification of soils.

Seasonal Variability of Soil pH

Seasonal changes in soil moisture, temperature, microbial activity, and plant growth can cause soil pH to vary. The interaction of the above factors and their effect on pH are not entirely understood. The seasonal effect is a result of the loss, formation, or accretion of salts during the various times of the year (Thomas, 1996). Salt concentration fluctuates as the soil wets and dries. As the soil dries, salt concentration increases, soluble cations replace exchangeable hydronium (i.e., H_3O^+) or aluminum ions, and the solution becomes more acid. Seasonal changes in temperature affect the solubility of carbon dioxide (CO_2) in water and the solution acidity. Carbon dioxide is more soluble at cool temperatures and makes the soil more acid (carbonic acid). Conversely, CO_2 is less soluble in warm seasons, but microbial respiration produces more CO_2 , so the net effect on pH is variable. Seasonal differences in the amount of carbonate and bicarbonate ions in solution result in variable pH.

Measuring Soil pH for Soil Taxonomy

The *Soil Survey Laboratory Methods Manual* (USDA, 2004) describes several methods used by the laboratory at the National Soil Survey Center to measure soil pH. The methods that relate to criteria in *Soil Taxonomy* (Soil Survey Staff, 1999) are described in this section. The reader is advised to study the laboratory methods companion document *Soil Survey Laboratory Information Manual* (USDA, 1995). This manual provides informative operational and conceptual definitions for all soil properties measured by the National Soil Survey Laboratory. Also, it describes the application of each property to soil classification, soil genesis, and geomorphology.

1) 1:1 H₂O and 1:2 0.01 molar (M) CaCl₂

1:1 H₂O is a mixture, by weight, of one part soil to one part distilled H₂O. It is the method most commonly used in the field because of the availability of water. Seasonal variations in soil pH can be detected with the 1:1 H₂O method; therefore, it is not used to determine family reaction classes in *Soil Taxonomy*. If pH varies widely, knowledge of this variability is important because of the effect of pH on crop performance and on some other aspects of land use.

1:2 0.01 M CaCl₂ is a mixture, by weight, of one part soil to two parts 0.01 M CaCl₂ solution. Calcium chloride (CaCl₂) pH is the standard used in *Soil Taxonomy* to differentiate acid and nonacid family reaction classes in mineral soils and euic and dysic family classes in organic soils. The 0.01 M CaCl₂ solution dampens the seasonal variation in soil pH by providing Ca²⁺ ions that displace the hydronium and aluminum ions from the colloid surfaces. The result is a pH measurement that remains somewhat invariable to the seasonal changes in pH. The use of the CaCl₂ solution also diminishes the seasonal effect of soluble salt concentration.

Regardless of the method used, increasing dilution (within limits) will raise the pH. The more dilute the soil:water ratio, the higher the measured pH. For example, a 1:1 H₂O pH is generally lower than 1:10 H₂O pH.

2) 1:1 1 normal (N) KCl

The primary use of the pH in 1:1 1 N KCl solution is to test for the presence of exchangeable aluminum. The absolute value of KCl pH bears a strong correlation with aluminum saturation. This higher concentrated salt solution displaces hydronium and aluminum ions completely, whereas 0.01 M CaCl₂ does not always do so. Aluminum, displaced by K⁺ on the exchange complex, consumes OH⁻ ions and increases [H⁺]. As a result, the solution pH is lowered. Generally, exchangeable aluminum is present if the 1 N KCl pH is 5.2 or less. If the 1 N KCl pH is more than 5.2, aluminum is non-exchangeable because of hydrolysis, polymerization, and precipitation. Therefore, in the highly weathered, low fertility "Acr" great groups of Oxisols, the criterion "1 N KCl pH > 5.0" indicates that aluminum toxicity is not a concern.

For soils that have a net negative charge (cation-exchange capacity), the 1:1 1 N KCl pH generally is about 1 pH unit lower than the 1:1 H₂O pH. Be aware that 1 N KCl significantly modifies the natural soil environment. Thus, the 1 N KCl pH is not reliable for interpreting the soil's fertility or crop production potential.

Delta pH

The comparison of KCl pH with H₂O pH provides an assessment of the nature of the net charge on the colloidal system. For example, highly weathered Oxisols with high amounts of iron oxihydrates have a net positive charge (anion-exchange capacity). If the content of organic matter is low or negligible in such soils, the 1:1 1 N KCl pH may be higher than the 1:1 H₂O pH. The difference in pH results from displacement of OH⁻ ions by Cl⁻ ions. The numerical difference in the values of pH measured in KCl and H₂O is referred to as the delta pH. When this difference is negative, the colloid has a net negative charge, and when positive, it has a net positive charge. This relationship is used as differentiae in the Anionic

subgroups of the Acric great groups of Oxisols, in which the delta pH (KCl pH minus 1:1 H₂O pH) is zero or positive. Delta pH is not estimated when the pH is higher than about 6.5.

Note: The difference in pH between 1:1 H₂O and 1:2 0.01 M CaCl₂ may also be positive or negative. However, the delta pH in Soil Taxonomy is not measured with 0.01 M CaCl₂. In order to completely exchange the aluminum ions, a much higher salt concentration is needed, and so 1 N KCl is used.

3) Oxidation pH

Acid sulfate soil formation occurs when sulfide minerals, such as pyrite, and/or elemental sulfur in reduced sulfidic sediments oxidize upon exposure to air through drainage or earth-moving operations. The oxidation products are jarosite and sulfuric acid. Jarosite undergoes hydrolysis in an oxidizing environment, releasing iron oxyhydrates and more sulfuric acids. This set of reactions is one of the most acid-producing reactions in soils. A sulfuric horizon is indicated if acid sulfate formation gives an end product pH of 3.5 or less.

Oxidation pH is used to test for the presence of sulfidic material and to predict the occurrence of sulfuric horizons. The laboratory procedure accelerates the natural formation of microbial acid sulfate. Microbial oxidation of sulfidic material is controlled by incubating a saturated soil sample in a closed container at room temperature. The sample is periodically stirred, so that the O₂ needed for the oxidation process is incorporated, and the pH (1:1 H₂O) is measured. The sample is given ample time (up to 8 weeks) to fully oxidize. When the change is a pH unit of less than 0.03, the oxidized pH is recorded. For a more rapid test, hydrogen peroxide is added to the soil. The result is violent effervescence and an extremely acid suspension, indicating the presence of acid sulfate material.

4) 1 molar (M) NaF pH

The pH of a suspension containing 1 g soil in 50 mL 1 M NaF is used as a criterion for the isotopic mineralogy class. This method tests for the presence of short-range order minerals. These minerals are commonly early products of the weathering of pyroclastic materials or are formed in spodic horizons in a humid climate. The action of 1 M NaF on these minerals releases hydroxide ions (OH⁻) to the soil solution and increases the pH. A 1 M NaF pH of more than 8.4 at 2 minutes after the NaF solution is added is a strong indicator (in non-calcareous soils) that short-range order minerals dominate the soil exchange complex.

Free carbonates in the soil can result in high NaF pH values without the presence of short-range order minerals. Therefore, the isotopic mineralogy class does not include soils with free carbonates.

Measuring Soil pH in the Field

Pocket pH meters, standard dyes, and paper pH indicator strips are commonly used when pH is measured in the field. Pocket pH meters can be used in 1:1 H₂O or any soil:salt solution. The meters must be well maintained and calibrated to be reliable. They are sensitive and can become faulty. Clean them as specified, keep them well calibrated, and do not leave them where they will be subject to excessively hot or cold temperatures.

Although they continue to improve, pH meters are less dependable than standard dyes, which are quite accurate. Soil pH measured with pH meters in a laboratory setting and then measured with

dye differs by a pH unit of no more than 0.3 when the dye is used carefully. Temperature extremes and prolonged exposure to sunlight can affect the reliability and longevity of dyes. Several kits are in use. Some of them include a neutral salt. As a result, the pH measured from different kits may vary. The same indicator dyes that are applied to 1:1 H₂O can be applied to 1:2 0.01 M CaCl₂ and 1:1 1 N KCl soil:water suspensions.

Paper pH indicator strips are bonded with dyes. They can be used in 1:1 H₂O or any soil:salt solution. They are as accurate as standard liquid dyes and are not so sensitive to temperature and sunlight. Unlike pocket pH meters, these strips are not subject to breakage and do not need to be calibrated and maintained. Indicator colors are easily distinguishable.

Contact

The contact for this technical note is the National Leader for Soil Classification and Standards, National Soil Survey Center, Lincoln, NE.

References

Soil Survey Staff. 1999. Soil taxonomy: A basic system of soil classification for making and interpreting soil surveys. 2nd ed. Natural Resources Conservation Service. United States Department of Agriculture Handbook 436.

(<http://soils.usda.gov/technical/classification/taxonomy/>)

Thomas, G.W. 1996. Soil pH and soil acidity. p. 475-490. *In* J.M. Bigham (ed.). Methods of soil analysis: Part 3—chemical methods. Soil Science Society of America Book Series No. 5. Soil Science Society of America and American Society of Agronomy, Madison, WI.

United States Department of Agriculture, Natural Resources Conservation Service. 1995. Soil survey laboratory information manual. Version No. 1.0. Soil Survey Investigations Report No. 45. (<http://soils.usda.gov/survey/nscd/lim/>)

United States Department of Agriculture, Natural Resources Conservation Service. 2004. Soil survey laboratory methods manual. Version No. 4.0. Soil Survey Investigations Report No. 42. (<http://soils.usda.gov/technical/lmm/>)